NOAA Office of Ocean Exploration Quick Look Report

Expedition Title: Bermuda: Search for Deep Water Caves 2009

Results (please check all disciplines in which this cruise collected data)	**Details** (please describe any novel discoveries in the discipline, answers such as "possible, awaiting data analysis" and "no apparent discoveries" are acceptable)
Bathymetric Mapping **X** Yes ☐ No	More than 150 linear km of seafloor along the continental shelf break and centered on the 100 m contour covering ~60-200 m water depths was mapped using multibeam including the entire perimeter of the main Bermuda Platform and ¾ of the Challenger Seamount.
New Species Discovered ☐ Yes **X** No	Biological collections will be carried out during the second phase of the project in 2010.
Bio-prospecting ☐ Yes **X** No	Possible bio-prospecting sampling may be carried out during the second phase of the project in 2010.
Habitat Range Extended **X** Yes ☐ No	A notable invasive species, the Lionfish, was plentiful around cave entrances and overhangs at water depths of 80 m or more. Attempts to eradicate this species from Bermuda waters will be much more difficult due to their abundance in deep waters. Analysis of fish and hard and soft coral vertical distributions are still underway.
Chemical Processes ☐ Yes **X** No	No apparent discoveries to date.
Biological Processes ☐ Yes **X** No	Investigations and biological sampling of deep caves will be carried out during the second phase of the project in 2010.
Geologic Processes **X** Yes ☐ No	A number of karstic sinkholes were discovered along the northern edge of the Bermuda Platform while numerous ledges, overhangs and possible cave entrances were discovered on the steep walls at the platform edge. Near vertical submarine cliff faces between ~80-160 m depths showed irregular relief including vertical gullies, sand floored ledges and landslides. The heads of several submarine landslide scarps were discovered around the perimeter of the Bermuda shelf break suggestive of significant mass wasting activity down the flanks of the seamount.
Physical Processes ☐ Yes x No	
Sub/ROV/AUV Dives **X** Yes ☐ No	ROV dives: Seabotix LBV200 dives - 33 video survey dives, 25 cumulative hours of dive time
New Technology **X** Yes ☐ No	At our request the manufactures of the RESON 7125 multibeam sonar system and PDS acquisition software developed and provided us with a beta version of the software and firmware to enable the collection of ultra-high resolution bathymetry data (<1m) at water depths in excess of 150m so that we could fulfill the mission goals of identifying potential cave mouths and voids along the upper slope wall of the Bermuda seamount. These modifications enabled us to run the system at 400 khz, with equal distant beam spacing and roll stabilization. A great deal of development and field testing time was put into perfecting these capabilities by both the CSUMB Seafloor Mapping team and the RESON staff prior to our departure for Bermuda. The success of these efforts paid off in our demonstrated ability to discover and precisely locate overhangs, tunnels and cavities only a few meters across that we then explored with our acoustically tracked ROV.
Maritime Cultural Heritage **X** Yes ☐ No	The wreck of the King George, a dredge sunk in 1930, was use to calibrate the multibeam sonar.
Outreach **X** Yes ☐ No	Newspaper article, *Delving into the unknown,* in the Bermuda Sun. Summary presentation and open discussion to Bermuda Government officials, scientists, and environmental consultants. Several local scientists participated in the at sea research.
Students Involved **X** Yes ☐ No	Three graduate students and two undergraduates directly participated and assisted with at sea research and data analysis.
Multidisciplinary **X** Yes ☐ No	This project combined the diverse talents and expertise of Texas A&M marine biologist and cave explorer Tom Iliffe with those of California State University, Monterey Bay seafloor mapping expert Rikk Kvitek.
Exploration of New Regions **X** Yes ☐ No	Other than standard hydrographic charts, only limited exploration had been conducted of the shelf break edge surrounding Bermuda. The contour lines of existing hydrographic charts were at significant variance from our considerable more detailed map.

Ocean Exploration Quick Look Report Required Elements

The Office of Ocean Exploration (OE) does not require a specific Quick Look Report format. Reports submitted under other requirements (e.g. Cruise Summary Report (CSR)) or Fisheries-Oceanography Coordinated Investigations (FOCI)) are acceptable. In all cases Quick Look Reports submitted to OE should contain the following elements:

Project title: Search for Bermuda's Deep Water Caves

Principal Investigator and institution: Thomas M. Iliffe, Texas A&M University at Galveston

Expedition title: Bermuda: Search for Deep Water Caves 2009

Expedition dates and itinerary:

5 Sept: Team members arrive in Bermuda
6-7 Sept: Set up and calibrate multibeam mapping equipment on R/V Endurance
8-18 Sept: Conduct multibeam mapping of the shelf edge of the Bermuda Platform and Challenger Seamount
19 Sept: Change out graduate and undergraduate student assistants
20-28 Sept: ROV investigations of points of interest discovered during the multibeam survey
29 Sept: Scuba dive at karstic natural bridge in 60 m water depths; public presentation of results
30 Sept: Team members depart Bermuda

Chief Scientist and institution: Thomas M. Iliffe, Texas A&M University at Galveston

Co-sponsors / partners / participating organizations:

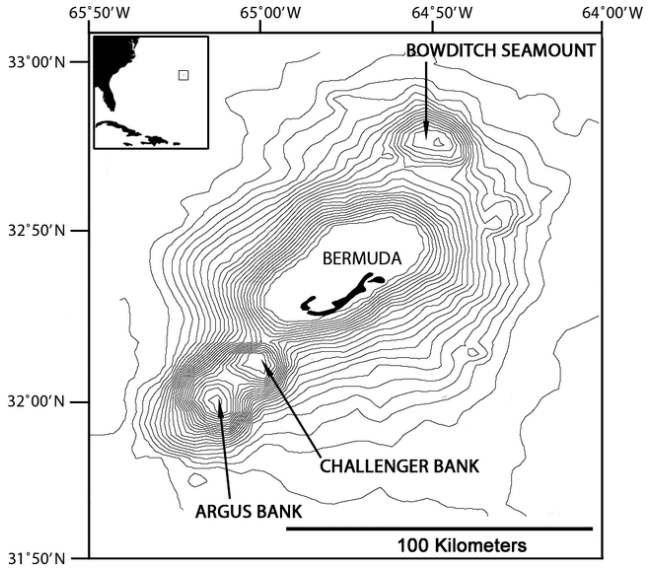
- Rikk Kvitek, Seafloor Mapping Lab at California State University, Monterey Bay
- Bermuda Zoological Society
- Bermuda Aquarium, Museum and Zoo
- Bermuda Underwater Exploration Institute
- Triangle Diving, Bermuda

Vessel Identification: R/V Endurance – owned and operated by the Bermuda Zoological Society

Primary Equipment:

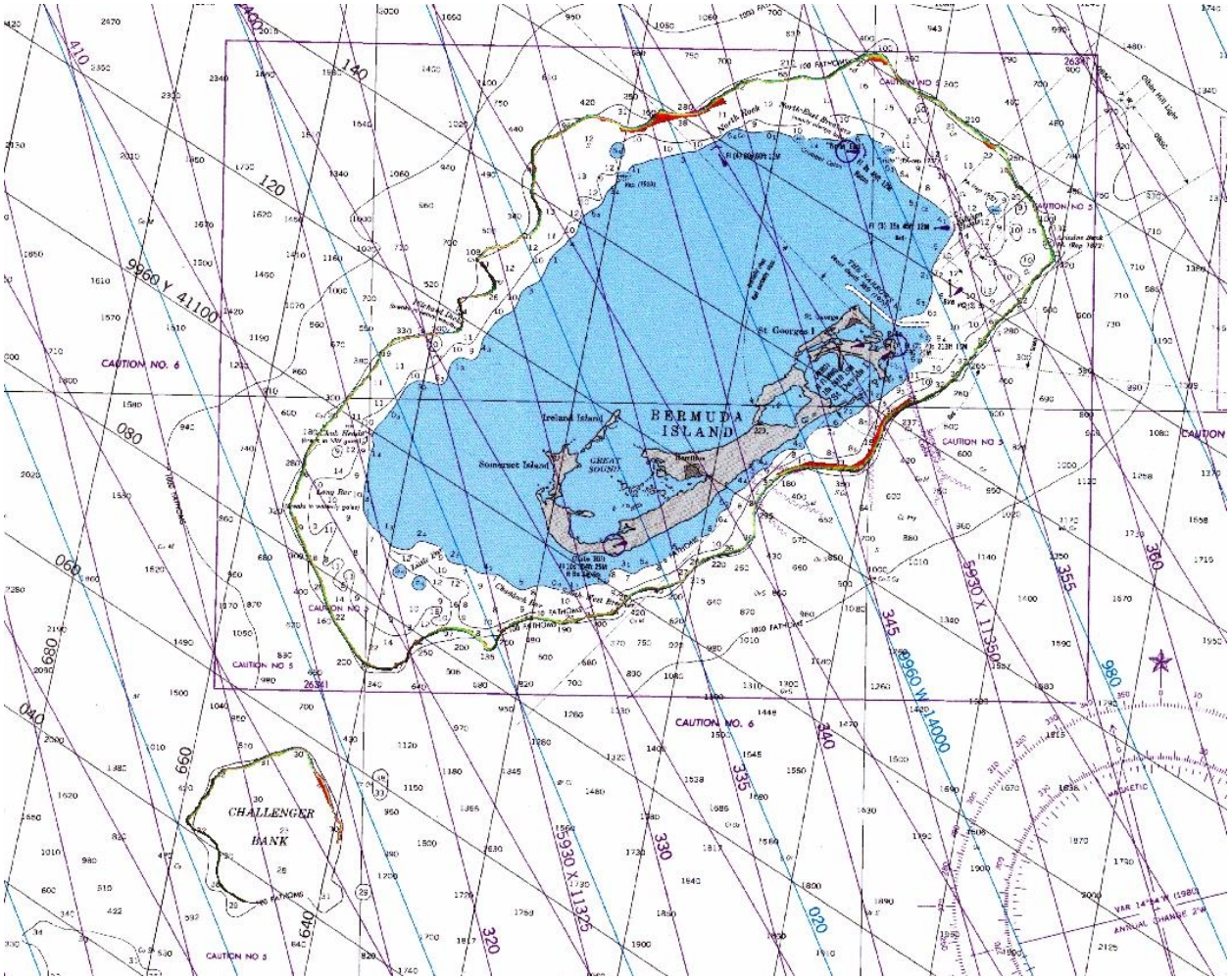
- Reson 7124 multibeam sonar system
- Trimble NetR5 GPS reference station
- CodaOctopus F185+ Precision Attitude & Positioning System
- Applied Microsystems SVplus sound velocity profilers
- Seabotix LBV200 Remotely Operated Vehicle (ROV) with video data acquisition and acoustic tracking systems

Geographic area of operations: Bermuda (32° 20'N, 64°50'W) and adjacent Challenger Seamount located 19 km southwest.

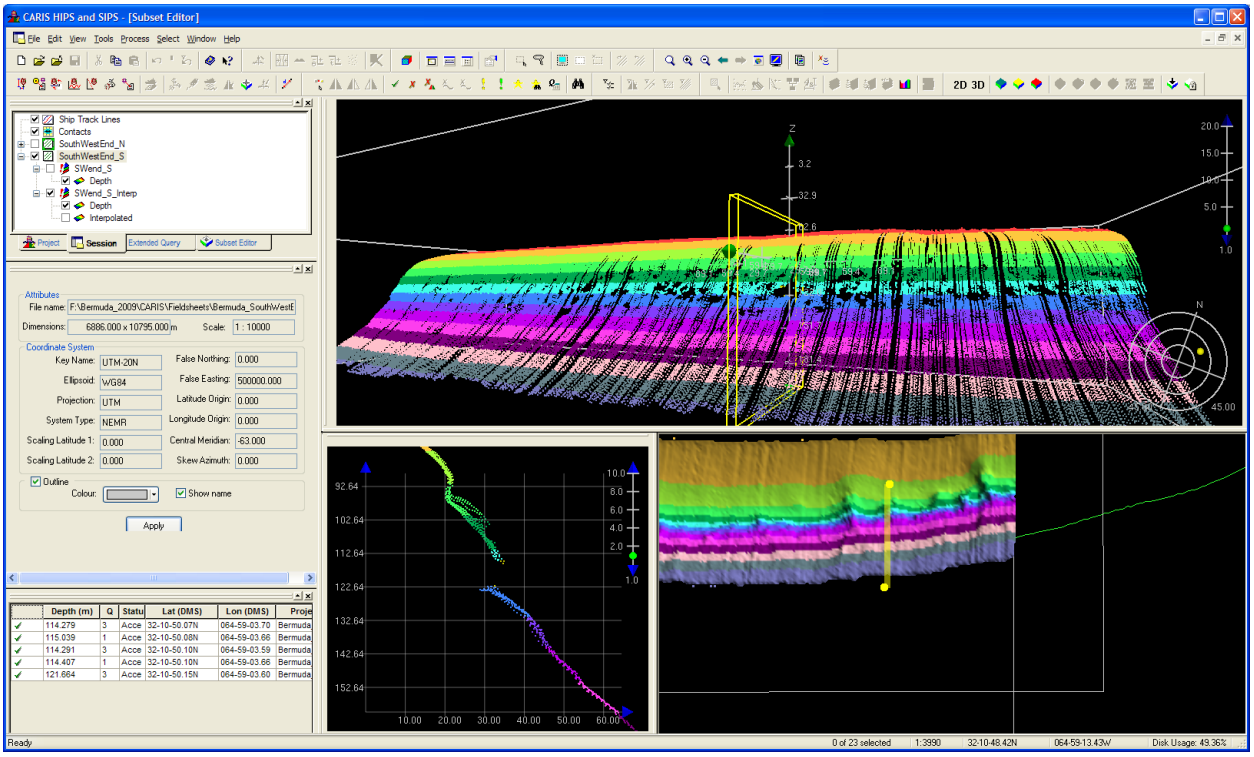


Summary of Expedition Objectives: (a list of the proposed objectives that were met as a result of the expedition)

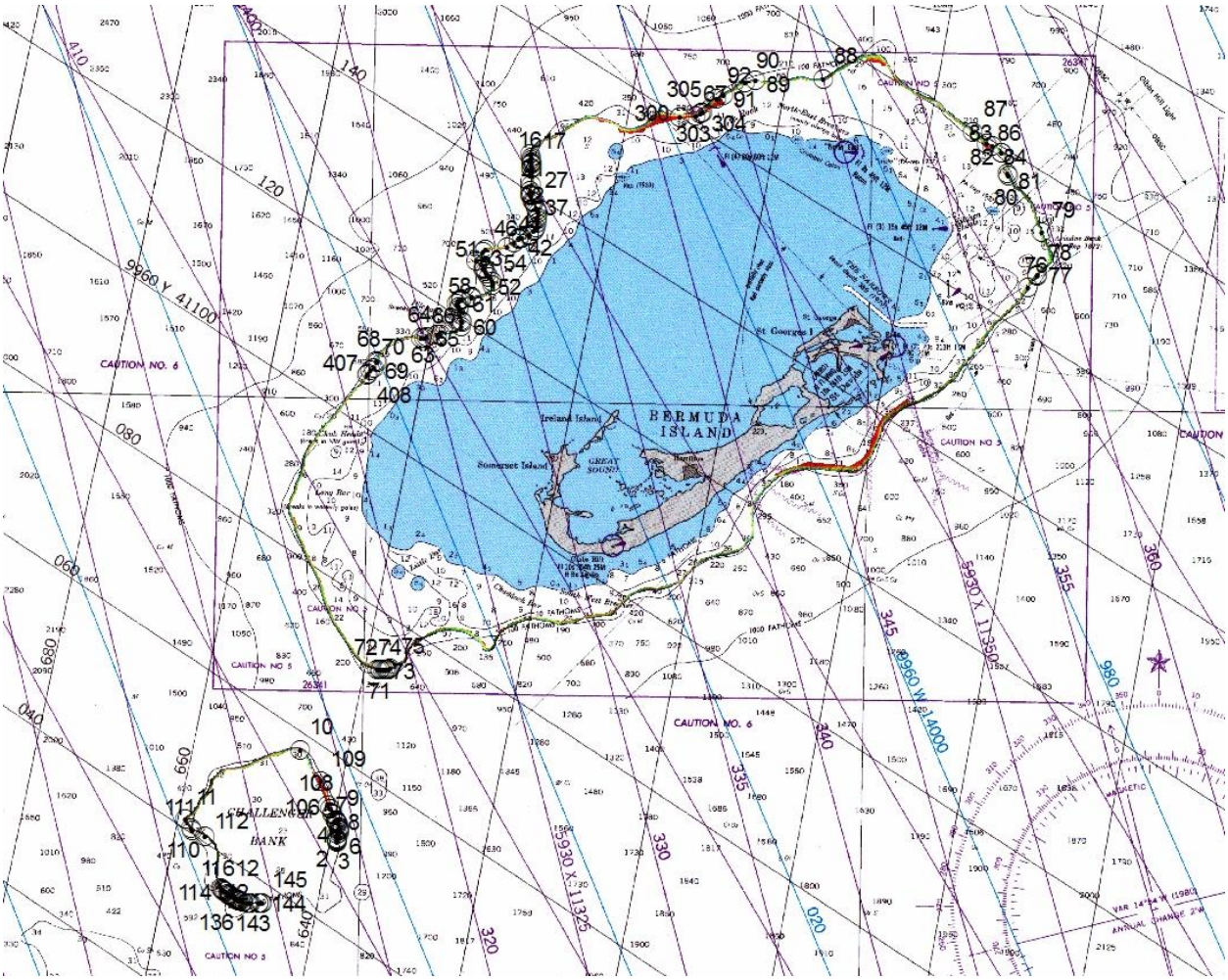
- Produce detailed, geo-referenced maps of the shelf edge of the Bermuda Platform and adjacent Challenger Bank using high resolution multibeam sonar. More than 100 kilometers of sea floor around the 100 m contour (including ~60-200 m depths) was mapped including the entire perimeter of the main Bermuda Platform and ¾ of the Challenger Bank.



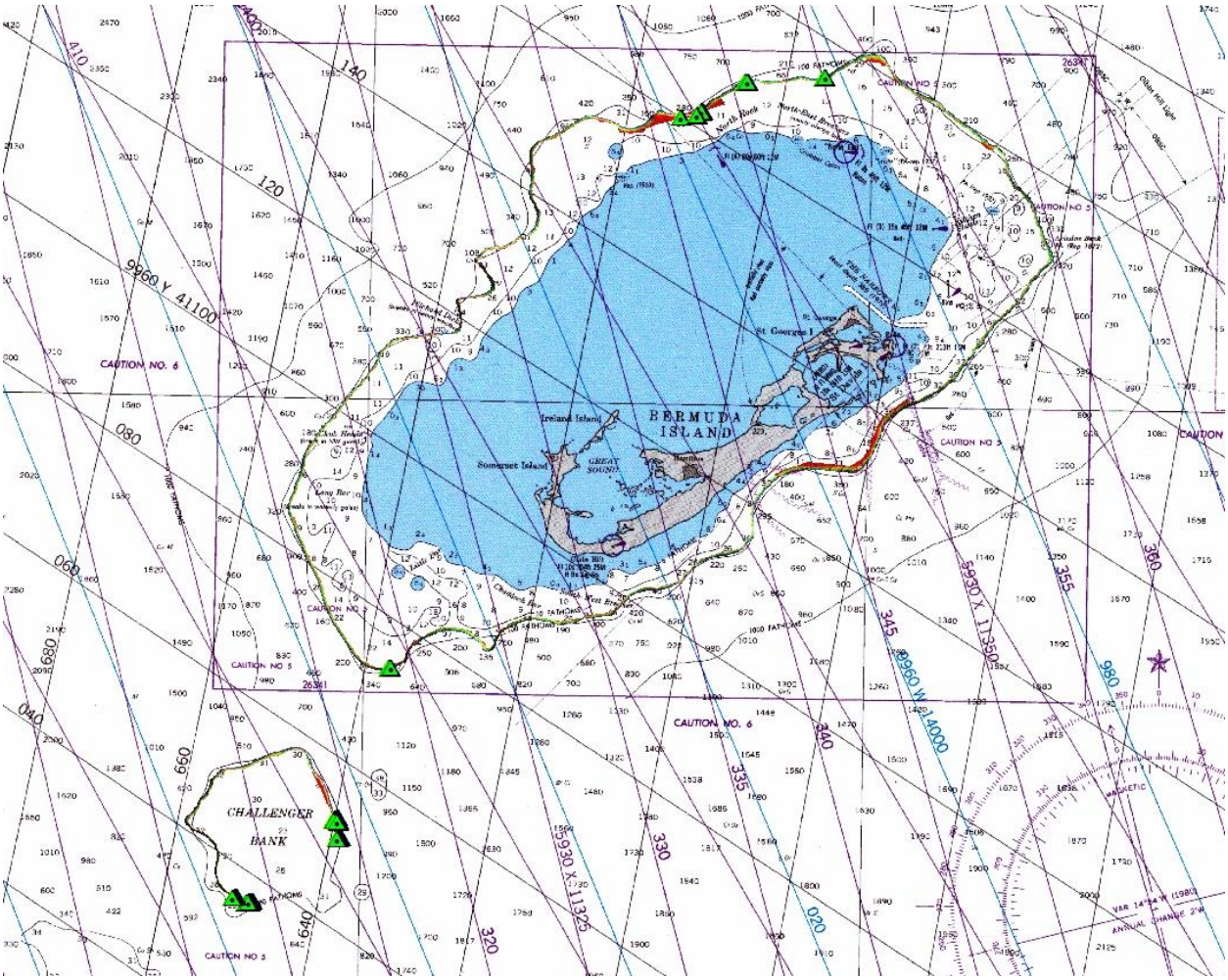
- Locate potential caves sites by examining multibeam profiles of the sea bottom to find consistent gaps in the data record which could indicate a void. Numerous sites were identified in this manner.



- Compile a list of “points of interest” or potential cave locations. More than 100 such sites were identified in this survey. These were primarily located locate at northwest, north, east and southwest sides of the main platform and on the southern and eastern margins of Challenger Bank



- Examine the highest potential points of interest in several areas around Bermuda using the ROV. Eighteen sites were explored in this fashion at locations on the north and southwest side of the main platform and on the east and south sides of Challenger Bank.

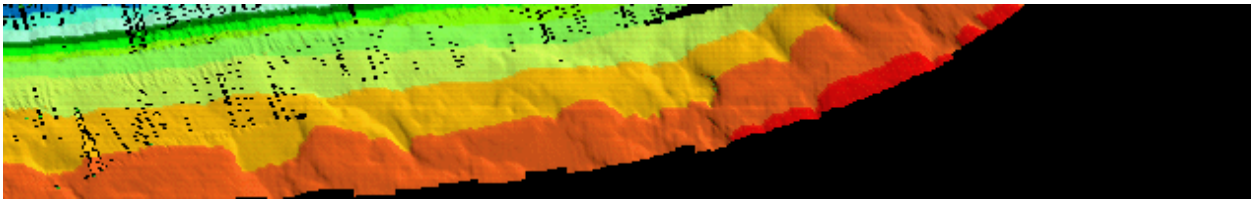


Milestones Achieved:

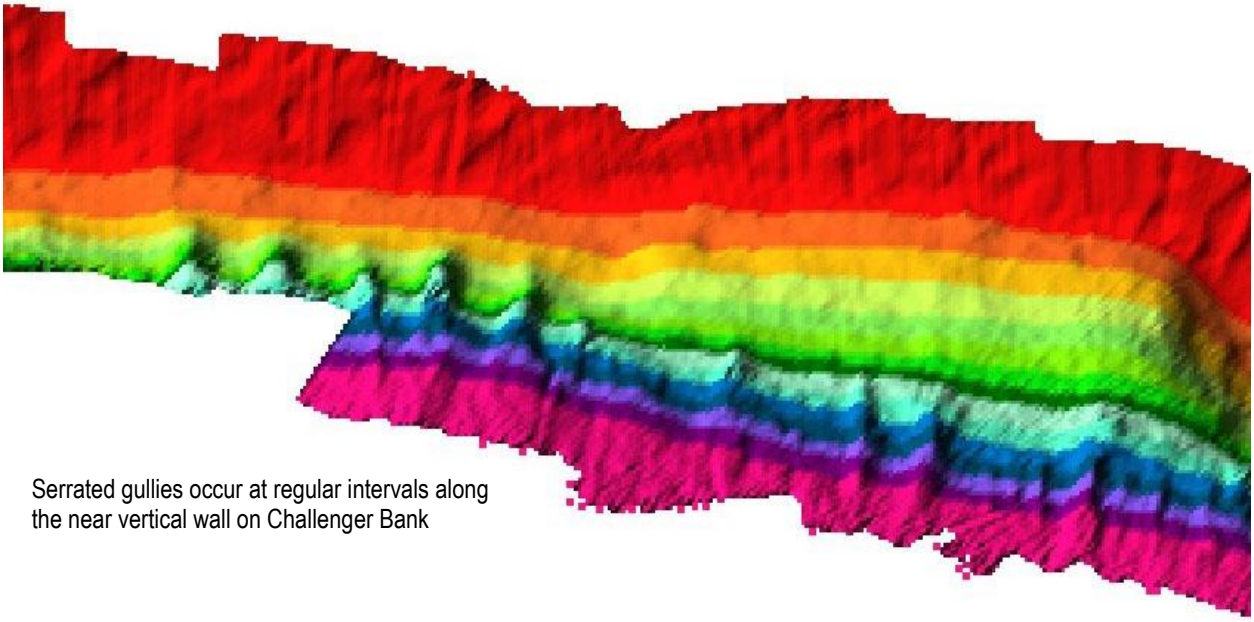
The multibeam sonar survey of the shelf break edge of the Bermuda Platform and adjacent Challenger Bank was carried out by Dr. Rikk Kvitek, Director of the Seafloor Mapping Lab at California State University, Monterey Bay. A Reson Seabat 7125 multibeam echosounder was used for data acquisition. Position and attitude control was provided by a CodaOctopus F185+ motion and navigation sensor. Sound velocity profiles were collected at intervals throughout the data acquisition with an Applied Microsystems SVP for correction of refraction artifacts and ray bending. Data were acquired with Triton Isis software and processed using CARIS HIPS multibeam processing software. Products included 3D point clouds, and digital elevation models (DEMs) used to look for potential cave sites. Data was visualized and explored in IVS Fledermaus as 3D point clouds to aid in the search for and identification of caves. Geotif images of the DEMs in shaded relied colored by depth and in gray scale were created for use during the ROV surveys to aid in navigation and piloting of the ROV.

The Seafloor Mapping Lab also provided a SeaBotix LBV200L2 ROV equipped with a 250 m umbilical and a depth rating to 200 m. The LBV200L2 is equipped with four powerful, oil-compensated, Brushless DC Thrusters. There is 1-lateral, 2-forward, and 1-vertical thruster, enabling maneuverability in four axes, just like a helicopter. The additional lateral thruster adds the capability to fly sideways, allowing the operator to keep either camera on target while piloting along a vertical surface. On-the-fly, 10-step variable power control to each axis allows for smooth video and sensor recording. The extremely small-diameter of the fiber optic umbilical presents less drag meaning the vehicle is controlled by the operator, not the umbilical. The Fiber Optic video system provides crystal-clear images from the standard high-res cameras. Both cameras have a total 270º field of view through180º rotation of the camera enclosure. The internal, fully-adjustable LED Lighting array provides brilliant, white light and tracks the color camera. The programmable Video Overlay displays heading, depth, temperature, cable turns, and time/date. The LBV 200 was used to explore sites identified in the preliminary multibeam data as potential cave area. The ROV pilot was able to view the position of both the surface vessel and ROV superimposed on the multibeam image. In addition to the video cameras and acoustic tracking, the ROV's onboard sonar system also aided in locating targeted seafloor features. The ROV flight path and georeferenced video imagery was digitally recorded in real-time for later playback. The flight path, recorded in Hypack software was converted to ArcGIS shapefiles for later display over the multibeam bathymetry imagery.

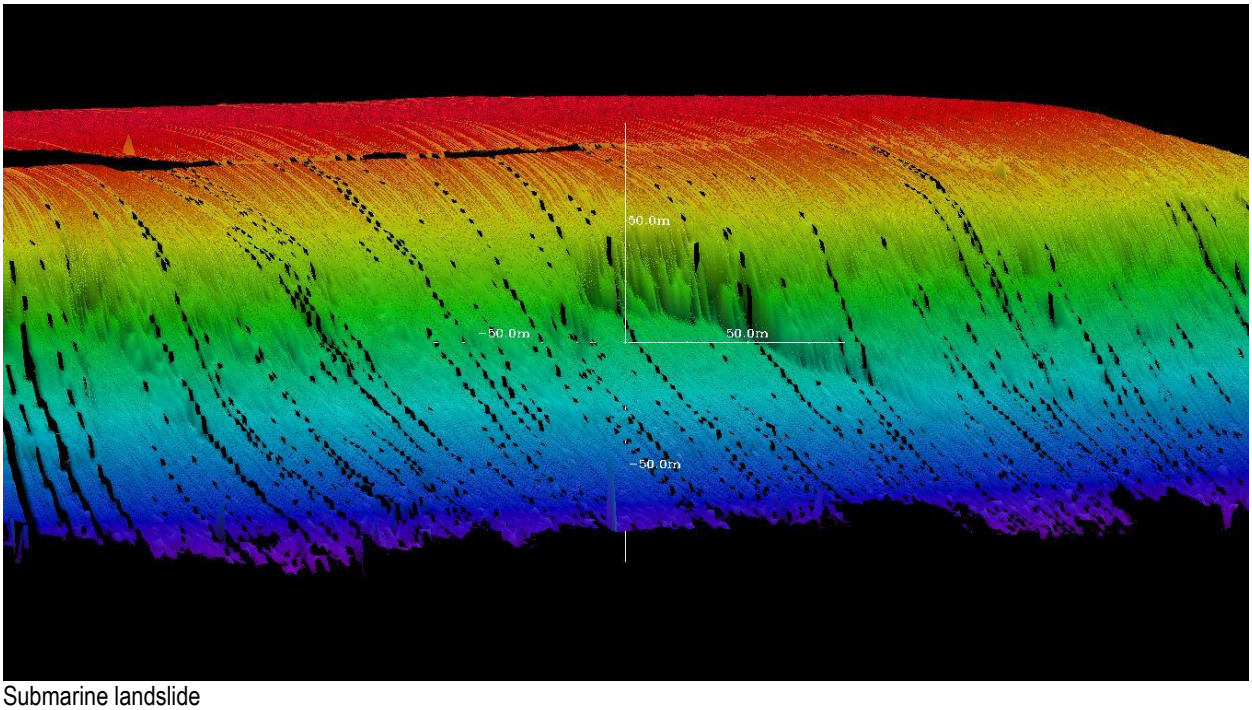
This first phase of the project consisted of a multibeam bathymetric survey of the platform edge between 60 and 200 m water depths, followed by ROV investigations of the most promising sites. Among the points of interest identified during the multibeam survey were enclosed karstic sinkholes, numerous ledges, overhangs, possible cave entrances, and near vertical submarine cliff faces between ~80-160 m depths with vertical gullies, sand floored ledges and landslides. The heads of several submarine landslide scarps were discovered around the perimeter of the Bermuda shelf break suggestive of significant mass wasting activity down the flanks of the seamount. During the calibration of the multibeam, the wreck of the dredge King George, was mapped in order to test the equipment. This ship was intentionally sunk in 1930 and lies upright on the bottom in 18 m water depths of the North Lagoon.



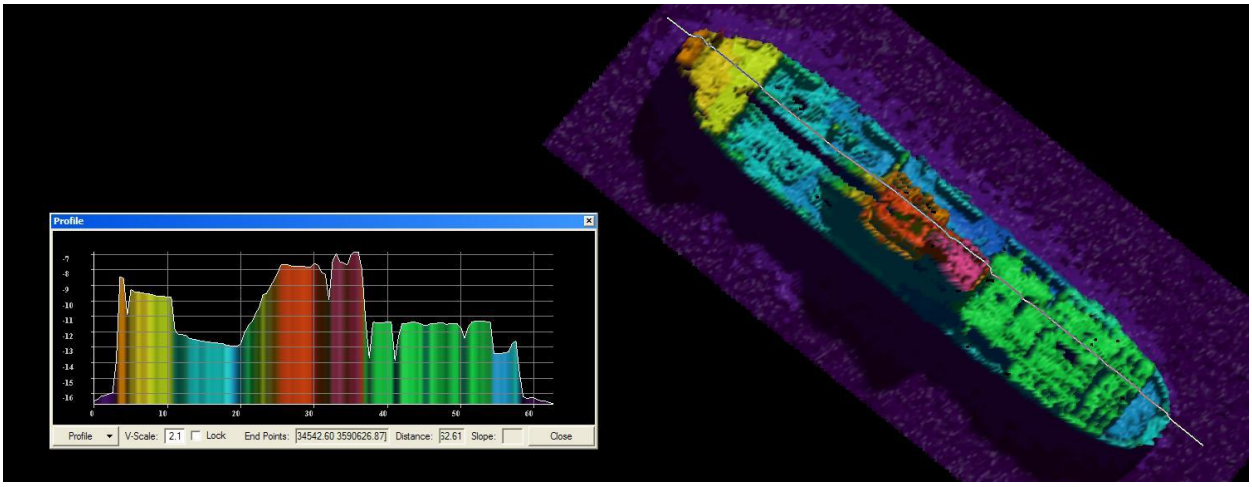
Sinkholes and channels near North Rock

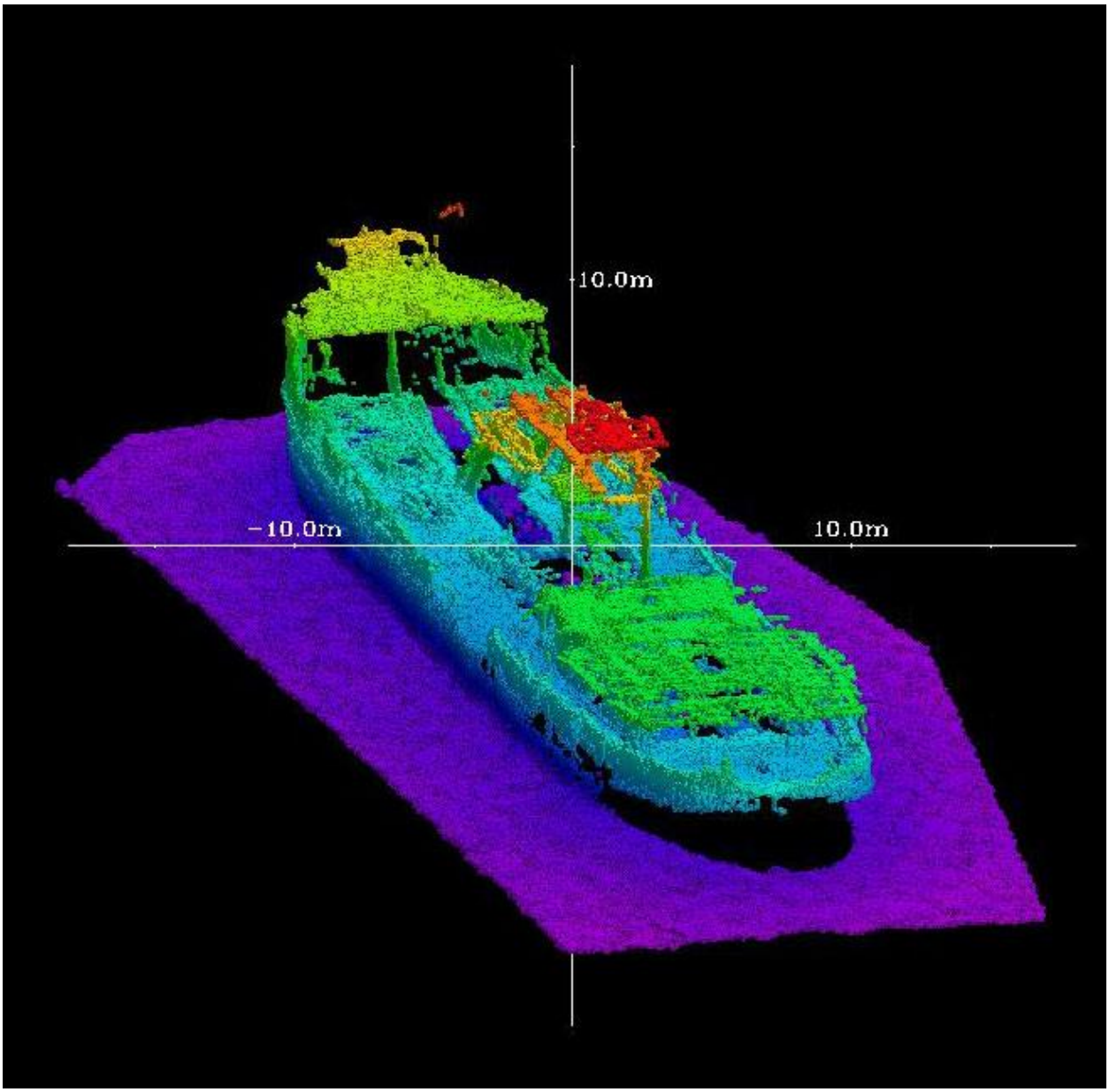


Serrated gullies occur at regular intervals along the near vertical wall on Challenger Bank



Submarine landslide

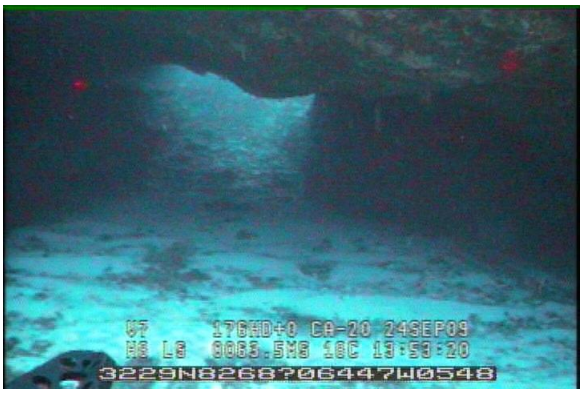




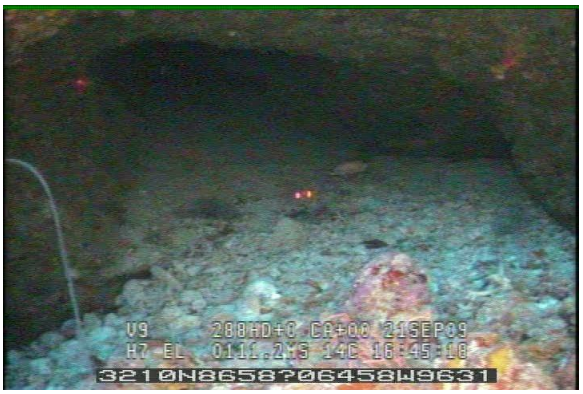
King George shipwreck

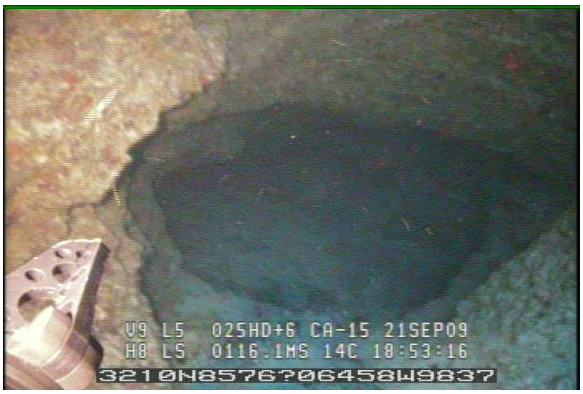
This project was selected as an OE Signature Project and as such is being featured on the OE website. The website will include video clips and photographs of both shipboard and undersea subjects as well as color coded bathymetric maps and related plots and diagrams. The PI was interviewed by the local press and an article on our research appeared in a national newspaper, the Bermuda Sun. In addition to generating high resolution bathymetric maps of the Bermuda Platform and

Challenger Bank, we produced numerous still image and digital video data. Among the points of interest that we identified with multibeam and then investigated with the ROV was a karstic natural bridge in 60 m water depths that was 10 m wide by 6 m high and 25 m long.



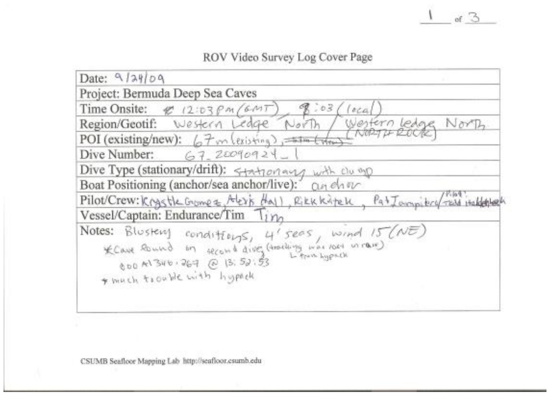
In addition, several promising looking tunnels were found on vertical walls at depths of 110-120 m.





Ongoing review of the ROV video archive will allow us to select sites with the greatest potential for diving investigations. The diving phase of the investigation will be conducted in summer or early fall of 2010 when weather conditions are optimal for Bermuda. During the next several months, the expert dive team will be provided with copies of video and still image archives that will enable us to select and plan the diving program and associated instrument placement and biological and geological studies and specimen collections.

Sample log entries:



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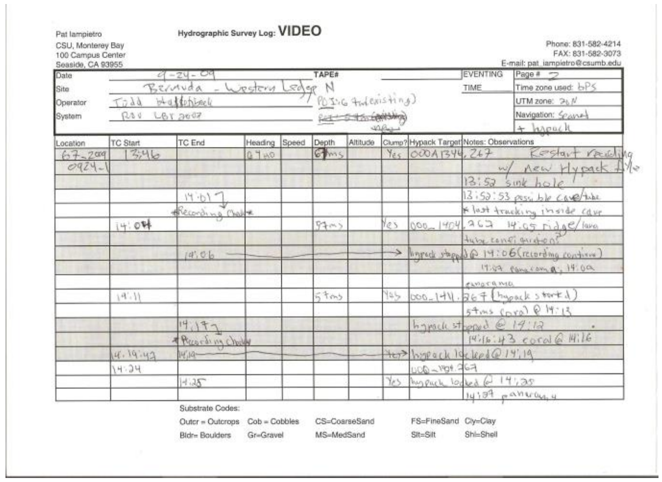
ROV Video Survey Log Cover Page

Date:	9/24/09
Project:	Bermuda Deep Sea Caves
Time Onsite:	12:03 PM (GMT), 9:03 (local)
Region/Geotif:	Western Ledge North / Western ledge North (NORTH ROCK)
POI (existing/new):	67m (existing), ~~(new)~~
Dive Number:	67_20090924_1
Dive Type (stationary/drift):	stationary with clump
Boat Positioning (anchor/sea anchor/live):	anchor
Pilot/Crew:	Krystle Gomez, Alexis Hall, Rikk Kvitek, Pat Iampietro/Todd Hallenbeck
Vessel/Captain: Endurance/Tim	Tim
Notes:	Blustery conditions, 4' seas, wind 15 (NE) *Cave found on second dive (tracking was lost in cave from hypack) 000A1344.267 @ 13:52:53 * much trouble with hypack

CSUMB Seafloor Mapping Lab http://seafloor.csumb.edu



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Hydrographic Survey Log: **VIDEO**

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E-mail: pat_iampietro@csumb.edu

Date	9-24-09	TAPE#	
Site	Bermuda - Western Ledge N	EVENTING TIME	
Operator	Todd Hallenbeck	POI: 67m (existing)	
System	ROV LBV 2007		
Page #	2	Time zone used:	GPS
UTM zone:	20N	Navigation:	Seanet + hypack

Location	TC Start	TC End	Heading	Speed	Depth	Altitude	Clump?	Hypack Target	Notes: Observations
67_2009 0924_1	13:46		040		67ms		Yes	000A1344.267	Restart recording w/ new Hypack file
									13:52 sink hole
		14:01 *Recording Check*							13:52:53 possible cave/tube
									* lost tracking inside cave
	14:04				57ms		Yes	000_1404.267	14:05 ridge/lava tube configuration?
		14:06						hypack stopped @ 14:06 (recording continue)	
									14:07 panorama, 14:09 panorama
	14:11				57ms		Yes	000_1411.267	(hypack started)
									57ms coral @ 14:13
		14:17 *Recording Check*						hypack stopped @ 14:12	14:16:43 coral @ 14:16
	14:19:47	14:19					Yes	hypack locked @ 14:19	
	14:24							000_1424.267	
		14:25					Yes	hypack locked @ 14:25	
									14:27 panorama

Substrate Codes:
Outcr = Outcrops Cob = Cobbles CS=CoarseSand FS=FineSand Cly=Clay
Bldr= Boulders Gr=Gravel MS=MedSand Slt=Silt Shl=Shell

Summary of Digital Data Collected:
All digital data products from both the multibeam and ROV surveys were provided to NOAA on USB hard drives. These included:
Bathymetry data
 xyz ascii soundings
 DEM raster grids
 Shaded relief geotifs gray scale
 Shaded relief geotifs colored by depth
 Contour shapefiles
ROV data
 Video data as digital files with UTC timestamp and georeferencing
 ROV track line shapefiles
 Target files with position and time in ascii format
Still image archive of expedition related activities

Summary of outreach and educational activities:

- Newspaper article in the **Bermuda Sun**, Oct. 2, 2009: *Delving into the unknown* – http://www.bermudasun.bm/main.asp?SectionID=24&SubSectionID=270&ArticleID=42991&TM=42831.99

- PowerPoint slideshow presentation and open discussion on the results of the Bermuda Seafloor Mapping and Deep Water Caves investigation to invited guests at the Bermuda Aquarium, Museum and Zoo Educational Auditorium on 29 Sept. Attendees included representatives of the Bermuda Government Departments of Fisheries, Environmental Protection, and Conservation Services, Bermuda Weather Service, Bermuda Aquarium, Bermuda Zoological Society, Bermuda Underwater Exploration Institute, Bermuda Institute for Oceanographic Sciences, Bermuda Whales Project, Reef Environmental Education Foundation, local dives shops, environmental consultants, independent researchers, and even a former Bermuda Premier – the highest elected office in the country.

- Invited article to be prepared for an upcoming issue of the Bermuda Zoological Society member's magazine **WILD**.

- Several local scientists and government officials either visited with us onshore or accompanied us on the Endurance for at sea activities.

Thoughts for the Future:
ROV biological/biodiversity exploration across a depth gradient at different sites around the platform could be carried out using the newly created multibeam base map to identify different habitat types. With this information, a number of research questions and hypotheses could be tested and answered, i.e. biotic and community differences related to depth, aspect, slope, texture, rugosity, and topographic feature type (overhang, gully, undercut, plateau, fissure, etc.). These characteristics would be identified in advance and the habitat classified accordingly from our existing multibeam results on the flats, break and slope.

Summary of Expedition Operations:
See above. All multibeam mapping and ROV position data has been combined in a GIS database that was supplied to NOAA.